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(54) **SYSTEM AND METHOD OF POWER MANAGEMENT FOR A HYBRID VEHICLE**

(71) Applicant: **GM GLOBAL TECHNOLOGY OPERATIONS LLC**, Detroit, MI (US)

(72) Inventors: **Joseph M. Tolkacz**, Novi, MI (US); **Norman Schoenek**, Novi, MI (US); **Min-Joong Kim**, Troy, MI (US)

(73) Assignee: **GM Global Technology Operations LLC**, Detroit, MI (US)

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CPC B60W 20/00

See application file for complete search history.

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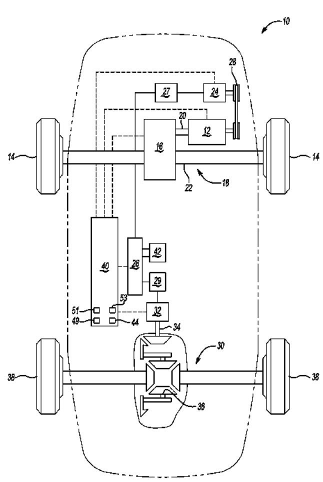
Primary Examiner — Thomas G Black
Assistant Examiner — Ana Thomas
(74) *Attorney, Agent, or Firm* — Quinn Law Group, PLLC

(57) **ABSTRACT**

A system and method of managing power in a hybrid vehicle are provided. The system includes an engine, first and second electronic power components, a power storage device, and a controller. The power storage device is configured to supply a power output to the second electronic power component necessary for the second electronic power component to drive a second set of drive wheels, in an electronic all-wheel drive mode. In steep grade environments, the power storage device is depleted at a higher rate, and may require a power input in addition to the power input of a conventional charge to adequately supply the second electronic power component with adequate power. To provide this power, the controller executes a series of control steps to increase a power output of the first electronic power component, by increasing the speed of the engine, thereby providing continuous power to the power storage device.

13 Claims, 2 Drawing Sheets



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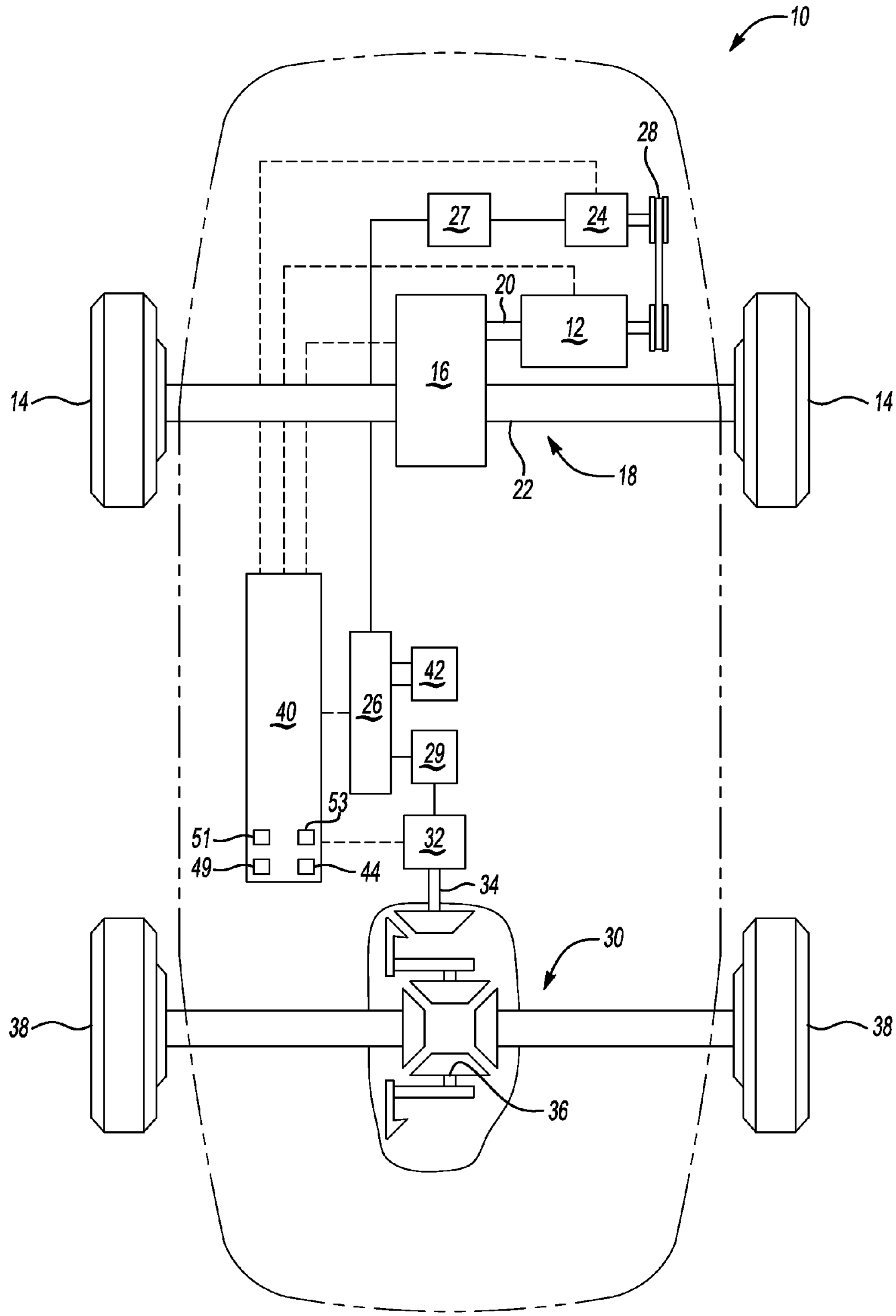
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Fig-1

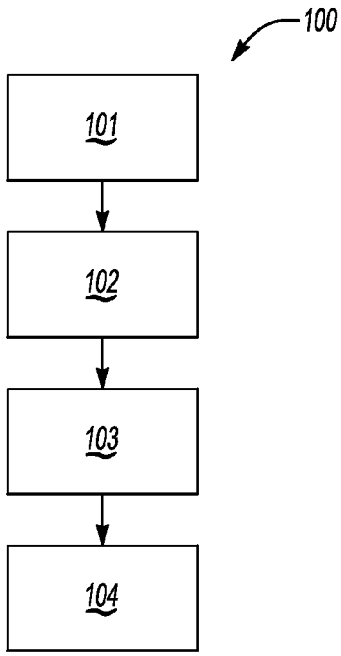

Fig-2

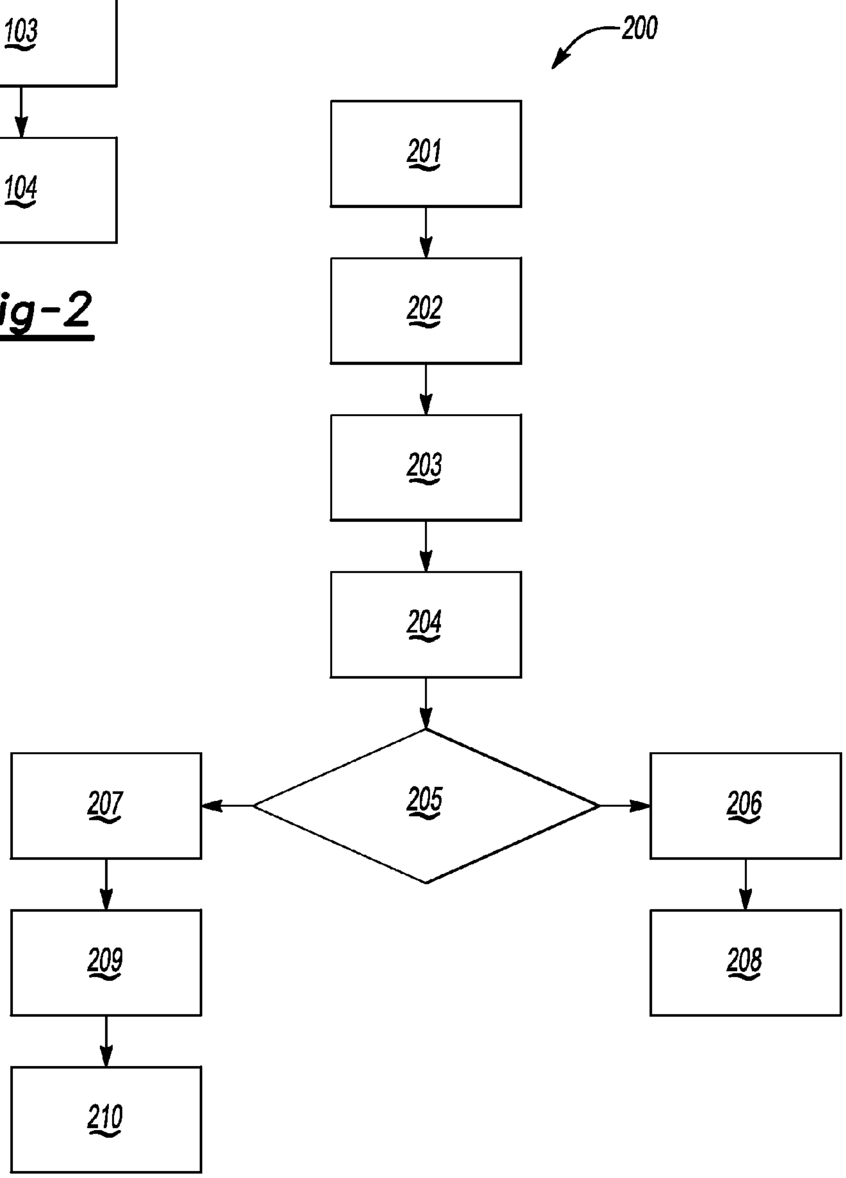

Fig-3

SYSTEM AND METHOD OF POWER MANAGEMENT FOR A HYBRID VEHICLE

TECHNICAL FIELD

The present teachings generally include a system and method of power management for a hybrid vehicle.

BACKGROUND

Some hybrid vehicles use a primary power source for the majority of the vehicle's propulsion needs and supplement that primary power source with an auxiliary power source, as needed. An auxiliary power source can benefit a hybrid vehicle in certain driving conditions, such as scaling large grades, i.e., steep inclines and declines.

In order to utilize the auxiliary power source, the auxiliary power source requires electric power from a power storage device. When climbing a significant grade, the auxiliary power source may diminish the stored charge of the power storage device more quickly, while operating in an electric-only mode or a hybrid mode.

SUMMARY

A system and method of managing power in a hybrid vehicle are provided. The system includes an engine, a transmission, first and second electronic power components, a power storage device, and a controller. The power storage device is configured to supply a power output to the second electronic power component to allow the second electronic power component to drive the vehicle via a second set of drive wheels. The power storage device is further configured to receive a power input from the first electronic power component.

In steep grade environments, the second electronic power component depletes the charge of the power storage device at a higher rate. Thus, the power storage device may require a power input in addition to the power input of a conventional charger to supply the second electronic power component with adequate power to drive the second set of drive wheels. To provide this additional power, the controller executes a series of control steps to increase the power output of the first electronic power component. The power output of the first electronic power component is increased by increasing the speed of the engine. The increased power output of the first electronic power component thereby provides the needed additional power to the power storage device and enables the power storage device to provide continuous power to the second electronic power component.

The steps executed by the controller, to produce continuous power to the power storage device, may include: determining a current state of charge of the power storage device and a target state of charge of the power storage device; calculating a target power output of the first electronic power component required to increase the state of charge of the power storage device from the current state of charge to the target state of charge; predicting a predicted resultant temperature of the first electronic power component as a result of producing the target power output; comparing the predicted resultant temperature of the first electronic power component to a predetermined temperature threshold for the first electronic power component; and executing one of a first control action when the predicted resultant temperature is below the predetermined temperature threshold and a second control action if the predicted resultant temperature exceeds the predetermined temperature threshold.

In executing the first control action, the controller commands the transmission to complete a gear downshift to increase the operating speed of the engine, thereby increasing the power output of the first electronic power component to allow the first electronic power component to produce the target power output required by the power storage device to supply continuous power to the second electronic power component.

In executing the second control action, the controller generates a revised power output for the first electronic power component, which allows the first electronic power component to supply the maximum power output to the power storage device allowed by hardware temperature constraints. The revised power output is based on a comparison of the predetermined temperature threshold to a series of predetermined values in a look-up table; and commands the transmission to complete a gear downshift to increase the operating speed of the engine to allow the first electronic power component to produce the revised power output.

The above features and advantages, and other features and advantages, of the present invention are readily apparent from the following detailed description of some of the best modes and other embodiments for carrying out the invention, as defined in the appended claims, when taken in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic illustration of an all-wheel drive hybrid vehicle.

FIG. **2** is a flow diagram detailing a method of managing power in the all-wheel drive hybrid vehicle.

FIG. **3** is a flow diagram detailing a second power management scheme.

DETAILED DESCRIPTION

The detailed description and the drawings or figures are supportive and descriptive of the invention, but the scope of the invention is defined solely by the claims. While some of the best modes and other embodiments for carrying out the claimed invention have been described in detail, various alternative designs and embodiments exist for practicing the invention defined in the appended claims.

Referring to Figures, a system and method of managing power in a hybrid-electric vehicle **10** are provided.

FIG. **1** illustrates a hybrid vehicle **10** equipped with an electric all-wheel drive system. The vehicle **10** includes an internal combustion engine **12** configured to drive the vehicle via a first set of wheels **14** through a transmission **16** and a first axle **18**.

The transmission **16** may be one of an automatic and manual transmission. The transmission **16** may be an automatic transmission, such as a multi-speed automatically-shiftable transmission that utilizes a gear train and multiple torque transmitting devices to generate discrete gear ratios between an input member **20** and an output member **22** of the transmission.

Although not shown, the existence of various gear trains, constructed from combinations of a range of planetary gear sets, and torque transmitting devices, such as clutches and/or brakes combined to form a functional automatic transmission, which will be appreciated by those skilled in the art.

Alternatively, the transmission **16** may be a manual transmission, such as a multi-speed manual transmission, which includes a manual gear shift selector and a cluster of gear sets.

The shift selector is operable for engaging each gear set to produce a specific gear ratio between the input **20** and the output **22**.

The vehicle **10** also includes a first electronic power component **24**. The first electronic power component **24** may be a first motor-generator unit, as shown in the example embodiment in FIG. **1**. The first electronic power component **24** may be connected directly to the engine **12** via a belt **28**. The first electronic power component **24** is further operatively connected to a power storage device **26** such as a high voltage battery or the like, having an output voltage of from about 60 VDC to about 300 VDC or higher. When the first electronic power component **24** operates as a motor, it receives electrical energy from the power storage device **26** to drive the transmission **16** or crank the engine **12**. When the first electronic power component **24** operates as a generator, it transmits electrical energy to the power storage device **26** to charge the power storage device **26**.

The hybrid vehicle **10** additionally includes a second axle **30**, which is configured as a fully electronic axle. The second axle **30** is operatively independent from the engine **12**, the transmission **16**, and the first electronic power component **24**. The second axle **30** includes a second electronic power component **32** having a second electronic power component output **34**. The second electronic power component **32** may be one of an electric motor and a second motor-generator unit. The second axle **30** further includes a rear differential **36** configured to receive torque from the second electronic power component output **34**, and further configured to transmit torque to the second set of drive wheels **38** to propel the vehicle **10**.

The second electronic power component **32** receives its electrical energy from the energy storage device **26**. Accordingly, the second electronic power component **32** is configured to drive the vehicle **10** independently from the engine **12** and to provide the vehicle **10** with an on-demand electric axle drive. The on-demand electric axle drive results in the vehicle **10** being operated in a purely electric vehicle or "EV mode." Furthermore, when both the first axle **18** and the second axle **30** are driven by their respective power sources, i.e., the engine **12** and the second electronic power component **32**, the vehicle **10** is endowed with all-wheel drive, and may operate in an "electric all-wheel drive mode."

The power storage device **26**, as described above, is electrically interconnected with the first electronic power component **24** and the second electronic power component **32**. A first power inverter module **27** may operatively connect the first electronic power component **24** and the power storage device **26**, and a second power inverter module **29** may operatively connect the second electronic power component **32** and the power storage device **26**. The first and second power inverter modules **27**, **29** may be configured to convert a power output from each of the respective first electronic power component **24** and the second electronic power component **32** to a suitable power input for the power storage device **26**.

The power storage device **26** is configured to receive power from the first electronic power component **24** and transmit power to the second electronic power component **32** and other electronic devices requiring power throughout the vehicle **10**.

The vehicle **10** further includes a controller **40** responsible for controlling the power management scheme of the vehicle **10**. The controller **40** may be a stand-alone unit, or be part of an electronic controller that regulates the operation of the engine **12** and the first and second electronic power components **24**, **32**. The controller **40** may be embodied as a server/host machine or distributed system, e.g., a digital computer or microcomputer, acting as a vehicle control module, and/or as a proportional-integral-derivative (PID) controller device having a processor **51**, and tangible, non-transitory memory **53** such as read-only memory (ROM) or flash memory. The controller **40** may also have random access memory (RAM), electrically erasable programmable read only memory (EEPROM), a high-speed clock, analog-to-digital (A/D) and/or digital-to-analog (D/A) circuitry, and any required input/output circuitry and associated devices, as well as any required signal conditioning and/or signal buffering circuitry. As envisioned herein, the controller **40** may be an electronic control unit (ECU) that is configured, i.e. programmed and equipped in hardware, to regulate and coordinate the hybrid propulsion of the vehicle **10**, which includes the operation of the engine **12**, the transmission **16**, and the first and second electronic power components **24**, **32**.

In relatively steep grade environments or other high power demand situations, the second electronic power component **32** may require an additional power output from the power storage device **26**, and, thus, may deplete the accumulated state of charge of the power storage device **26** at a higher rate, relative to more mild grades, in order to maintain operation in the EV mode or the electric all-wheel drive mode. In such situations, in order to provide adequate power to the second electronic power component **32** to maintain operation in the EV mode or the electric all-wheel drive mode, additional charge, in excess of that supplied by a conventional charger **42**, may be needed by the power storage device **26**.

To provide this additional charge to the power storage device **26**, the controller **40** executes a series of control steps to manage the power in a hybrid vehicle **10**, as detailed by the present method **100**, an example of which is shown in FIG. **2**. In managing the power of the vehicle **10**, the controller **40** increases a power output of the first electronic power component **24**, by increasing the speed of the engine **12**. The increased power output of the first electronic power component **24** to the power storage device **26** allows the power storage device **26** to provide continuous power to the second electronic power component **32**, as detailed in FIGS. **2** and **3**.

Referring to FIG. **2**, the controller **40** executes the present method **100** for managing power in the hybrid vehicle **10**. At step **101**, the controller **40** executes a first power management scheme, wherein the controller **40** determines an engine speed for the engine **12** and an engine torque for the engine **12** based on a first user input. The first user input may be one of an acceleration request and a declaration request, e.g., as requested by a driver of the vehicle **10** via a throttle or brake pedal, respectively.

At step **102**, the controller **40** detects a request to transition from the first power management scheme to a second power management scheme **200** (detailed in FIG. **3**). The second management scheme **200** includes providing additional power to the power storage device **26** with the first electronic power component **24** to allow the power storage device **26** to supply the second electronic power component **32** with continuous power. Supplying the second electronic power component **32** with continuous power allows the vehicle **10** of FIG. **1** to maintain operation in the "EV mode" or the "electric all-wheel drive mode", when the power storage device **26** experiences a high demand situation, such as when the vehicle **10** scales a large grade. In the example embodiment of FIG. **1**, the first electronic power component **24** is a motor-generator unit.

At step **103**, the controller **40** transitions the vehicle **10** of FIG. **1** from the first power management scheme to the second power management scheme **200**. At step **104**, the controller **40** executes the second power management scheme **200**.

The second power management scheme **200** is detailed in FIG. **3**. At step **201**, the controller **40** of FIG. **1** determines a current state of charge of the power storage device **26** and a target state of charge of the power storage device **26**, and calculates the delta thereof. At step **202**, the controller **40** utilizes the delta state of charge calculated at step **201**, to calculate a target power output of the first electronic power component **24** required to increase the state of charge of the power storage device **26** from the current state of charge to the target state of charge.

At step **203**, the controller **40** estimates a predicted resultant temperature of the first electronic power component **24** as a result of producing the target power output calculated at step **202**. In estimating the predicted resultant temperature, the controller **40** may take into account the capabilities of a cooling system (not shown) incorporated in the vehicle **10**.

At step **204**, the controller **40** compares the predicted resultant temperature of the first electronic power component **24** to a predetermined temperature threshold **44** for the first electronic power component **24**. The predetermined temperature threshold **44** may be stored on the electrically erasable programmable read-only memory of the controller **40**.

At step **205**, the controller **40** executes one of a first control action **206** and a second control action **207**. The controller **40** may execute the first control action **206**, when the predicted resultant temperature is less than the predetermined temperature threshold **44** of the first electronic power component **24**. The controller **40** may execute the second control action **207**, when the predicted resultant temperature exceeds the predetermined temperature threshold **44** of the first electronic power component **24**.

In executing the first control action **206**, at step **208**, the controller **40** commands the transmission **16** to complete a gear downshift to increase the operating speed of the engine **12**. Increasing the operating speed of the engine **12** increases the power output of the first electronic power component **24**, thus allowing the first electronic power component **24** to produce the target power output, as calculated at step **202**, to the power storage device **26**. With this additional power, the power storage device **26** is capable of providing continuous power to the second electronic power component **32**.

As a result of the predicted resultant temperature being in excess of the predetermined temperature threshold **44** for the first electronic power component **24**, the controller **40**, of FIG. **1**, executes the second control action **207**. In executing the second control action **207**, the controller **40** ascertains the maximum amount of power output, i.e., the revised power output, of the first electronic power component **24** that may be produced without exceeding the predetermined temperature threshold **44**, i.e. temperature constraints of the hardware components of the first electronic power component **24**.

At step **209**, the controller **40** compares the predetermined temperature threshold **44** to a series of predetermined values in a regression model or look-up table **49** to generate the revised power output for the first electronic power component **24**. Look-up tables, databases, data repositories or other data stores described herein may include various kinds of mechanisms for storing, accessing, and retrieving various kinds of data, including a hierarchical database, a set of files in a file system, an application database in a proprietary format, a relational database management system (RDBMS), etc. Each such data store may be included within a computing device employing a computer operating system such as one of those mentioned above, and may be accessed via a network in any one or more of a variety of manners. A file system may be accessible from a computer operating system, and may include files stored in various formats. An RDBMS may employ a Structured Query Language (SQL) in addition to a language for creating, storing, editing, and executing stored procedures.

At step **210**, the controller **40**, commands the transmission **16** to complete a gear downshift to increase the operating speed of the engine **12** to allow the first electronic power component **24** to produce the revised power output, as calculated at step **209**. This increases the amount of power supplied to the power storage device **26** to supplement power to the second electronic power component **32**.

The detailed description and the drawings or figures are supportive and descriptive of the invention, but the scope of the invention is defined solely by the claims. While some of the best modes and other embodiments for carrying out the claimed invention have been described in detail, various alternative designs and embodiments exist for practicing the invention defined in the appended claims.

The invention claimed is:

1. A method of managing power in a hybrid vehicle having an engine and a transmission, the method comprising:

executing, via a controller, a first power management scheme, wherein the controller determines an engine speed and an engine torque based on a first user input, the first user input defined as one of an acceleration request and a deceleration request;

detecting, via the controller, a request to transition the vehicle from the first power management scheme to a second power management scheme;

transitioning the vehicle, via the controller, from the first power management scheme to the second power management scheme; and

executing the second power management scheme, via the controller, such that a first electronic power component provides additional power to a power storage device and the power storage device provides continuous power to a second electronic power component, wherein executing the second power management scheme includes:

determining a current state of charge and a target state of charge of the power storage device;

calculating a target power output of the first electronic power component required to increase the state of charge of the power storage device from the current state of charge to the target state of charge;

estimating a predicted resultant temperature of the first electronic power component as a result of producing the target power output;

comparing the predicted resultant temperature of the first electronic power component to a predetermined temperature threshold for the first electronic power component;

executing one of a first control action and a second control action, wherein:

the controller executes the first control action when the predicted resultant temperature is below the predetermined temperature threshold, such that the first control action includes commanding, via the controller, the transmission to complete a gear downshift to increase the operating speed of the engine, such that the first electronic power component produces the target power output; and

the controller executes the second control action when the predicted resultant temperature exceeds the predetermined temperature threshold, such that the second control action includes:

generating, via the controller, a revised power output for the first electronic power component based on the predetermined temperature threshold of the first electronic power component by matching the predetermined temperature threshold to one of a series of predetermined power output values that correspond to predetermined temperature values in a look-up table; and

commanding, via the controller, the transmission to complete a gear downshift to increase the operating speed of the engine, such that the first electronic power component produces the revised power output.

2. The method of claim **1**, wherein the first electronic power component is a first motor-generator unit.

3. The method of claim **1**, wherein the engine is configured to drive the vehicle via a first set of drive wheels, and wherein the a second electronic power component is configured to drive the vehicle via a second set of drive wheels, such that the second electronic power component has a second electronic power component output operatively connected to a rear differential, the rear differential being configured to receive torque from the second electronic power component output and further configured to transmit torque to the second set of drive wheels.

4. The method of claim **3**, wherein the second electronic power component is one of an electric motor and a second motor generator unit.

5. A system for managing power in an all-wheel drive hybrid vehicle comprising:

an internal combustion engine configured to drive the vehicle via a first set of drive wheels;

a transmission configured to receive torque from the internal combustion engine and adjust an engine speed of the internal combustion engine;

a first electronic power component configured to start the engine;

a second electronic power component having a second electronic power component output, the second electronic power component configured to drive the vehicle via a second set of drive wheels;

a power storage device electrically interconnected with the first electronic power component and the second electronic power component, the power storage device configured to receive power from the first electronic power component and further configured to transmit power to the second electronic power component; and

a controller configured to:

execute a first power management scheme, wherein executing the first power management scheme includes determining a desired engine speed for the engine and a desired engine torque for the engine based on a first user input, the first user input defined as one of an acceleration request and a deceleration request;

detect a request to transition the vehicle from a first power management scheme to a second power management scheme;

transition the vehicle from the first power management scheme the second power management scheme in response to the request; and

execute a second power management scheme, wherein executing the second power management scheme includes increasing a power output of the first electronic power component to provide additional power to the power storage device, and

wherein increasing a power output of the first electronic power component to provide additional power to the power storage device includes:

determining a current state of charge of the power storage device and a target state of charge of the power storage device;

calculating a target power output of the first electronic power component required to increase the state of charge of the power storage device from the current state of charge to the target state of charge;

predicting a predicted resultant temperature of the first electronic power component as a result of producing the target power output;

comparing the predicted resultant temperature of the first electronic power component to a predetermined temperature threshold for the first electronic power component; and

executing one of a first control action and a second control action, wherein:

the controller executes the first control action when the predicted resultant temperature is below the predetermined temperature threshold, such that the first control action includes commanding the transmission to complete a gear downshift to increase the operating speed of the engine, such that the first electronic power component produces the target power output; and

the controller executes the second control action when the predicted resultant temperature exceeds the predetermined temperature threshold, such that the second control action includes:

generating a revised power output for the first electronic power component based on the predetermined temperature threshold by matching the predetermined temperature threshold to one of a series of predetermined power output values that correspond to predetermined temperature values in a look-up table; and

commanding the transmission to complete a gear downshift to increase the operating speed of the engine, such that the first electronic power component produces the revised power output.

6. The system of claim **5**, wherein the first electronic power component is a first motor-generator unit.

7. The system of claim **5**, wherein the second electronic power component is one of an electric motor and a second motor-generator unit.

8. The system of claim **7**, wherein the second electronic power component is a second motor-generator unit.

9. The system of claim **7**, wherein the second electronic power component is an electric motor.

10. The system of claim **5**, wherein the power storage device is a high voltage battery pack.

11. The system of claim **5**, wherein the system further includes a rear differential configured to receive torque form the second electronic power component output and transmit torque to the second set of drive wheels.

12. The system of claim **5**, wherein the transmission is a manual transmission.

13. The system of claim **5**, wherein the transmission is an automatic transmission.

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